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SIMPLE TECHNIQUE FOR TWO-PHOTON ABSORPTION MEASUREMENTS IN POLYMERIC WAVEGUIDE CHANNELS

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Abstract

A simple technique for two-photon absorption measurements by pulse shape deformation in channel waveguides is described. Measurements on a ps time scale are performed. Results are in good agreement with literature values.

Introduction

The Two Photon Absorption (TPA) is an important parameter in determining whether a third-order nonlinear material is suitable for all-optical switching or not.[1] We measured the TPA of the DANS-polymer of Akzo-Nobel by analysing the pulse shape deformation of pulses travelling through a SiO_xN_y waveguide with a polymer cladding. In the presence of TPA the power in a channel waveguide can be written as:[2]

$$P(z) = P_0 \frac{\alpha}{(\alpha + \beta P_0)\, e^{\alpha z} - \beta P_0} \qquad (1)$$

where α and β are modal linear absorption and two photon absorption respectively. P_0 is the peak power at the on set (z=0) of the non-linear region. Instantaneous response is assumed. The modal two photon absorption coefficient is related to the material two photon absorption β_m according to:

$$\beta = Q_2 \beta_m \qquad (2)$$

where Q_2 is an efficiency parameter which can be calculated from the variation theorem.[2,3] Equation 1 is a nonlinear relation between the input and output power of a waveguide. Therefore pulses travelling through the waveguide will be deformed. The description of this deformation can be simplified to the one dimensional full width at half maximum value (FWHM). The model can be evaluated and pulse width changes can be determined for several values of α, $P_0\beta$ and propagation length L. The relative FWHM is a function f which can be written as:

$$FWHM_{rel} = f\,(\alpha_{DANS}, P_0\beta) \qquad (3)$$

This function is shown graphically in figure 3.

Experimental set-up

The waveguide is a 4 layer stack of SiO_2 (n=1.45 @ λ=1.053µm), SiO_xN_y (n=1.76, t=0.2µm), Si_3N_4 (n=2, t=0.1µm) and a polymer layer serving as a cladding. In the coupling regions an index matching SiO_xN_y layer is used instead (see figure 1). The ridge is defined with a 5nm step in the Si_3N_4 layer and has a width of 8µm.

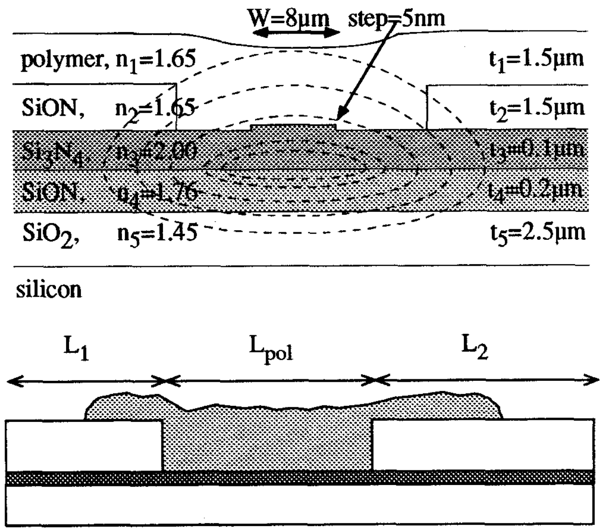

figure 1 The used channel structure. The intensity profiles give an impression of the localisation of the electrical field (upper). Cross section of the channel waveguide for the TPA measurements with relevant definitions. The optical power flows from left to right (lower).

The laser source is a mode-locked Q-switched Nd:YLF laser producing at a repetition rate of 134 Hz bursts consisting of 100ps FWHM pulses. A pulse picker is used for picking the highest intensity pulse out of the pulse train. The trigger timing is shown in the inset of figure 2. In this way high intensity pulses are obtained with a very low average power present in the suppressed which is important in avoiding thermal degradation of the end faces of the waveguides. We observed 75% of the optical power present in the high intensity pulses. The sampling oscilloscope is triggered on the high intensity pulses which are delayed with a mono modal fibre for compensating the internal delay of the oscilloscope. The observed signal shows a time jitter having a Gaussian time distribution with an RMS value of 50 ps.

The pulse shape deformation measurements are performed on two channel waveguides with a length of 5 cm. The length of the non-linear region is 1 and 4 cm respectively. The definitions are shown in figure 1.

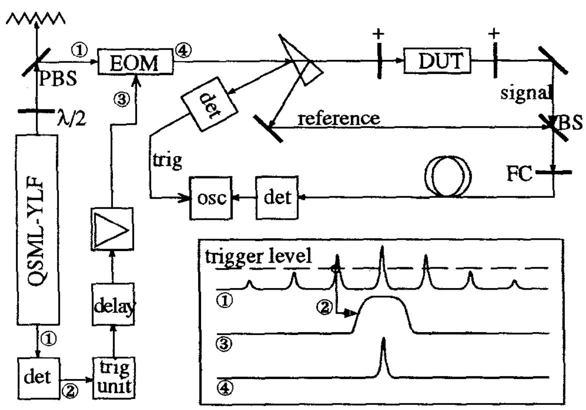

figure 2 The measurement set-up for the TPA measurements. The inset shows the timing at different positions in the set-up. Optical signals are represented by filled arrows. (P)BS: (polarising) beam splitter, EOM: electro-optic modulator, det: detector, OSC: sampling oscilloscope, λ/2: half wave plate, DUT: device under test.

Results

For the channels the input and output pulses are measured and averaged 32 times. The measured jitter is used to calculate the FWHM of the pulses from the measured FWHM.

Device	channel 31		channel 31		channel 34	
Quantity	in	out	in	out	in	out
L_1 [mm]	10		10		5	
L_2 [mm]	30		30		5	
L_{pol} [mm]	1		1		4	
W [μm]	8		8		8	
P [μW]	29	0.32	280	0.87	105	0.24
P_{peak} [W]	1100	12.5	10600	31	4180	8.6
$FWHM_{rel}$	0.992		1.062		1.118	

table 1 Experimental data used for the calculation of the TPA of the DANS polymer of Akzo Nobel.

The rise time of the detector and the sampling head are 7ps and 10ps respectively. The measured data are presented in table 1 and drawn as horizontal lines in figure 3.

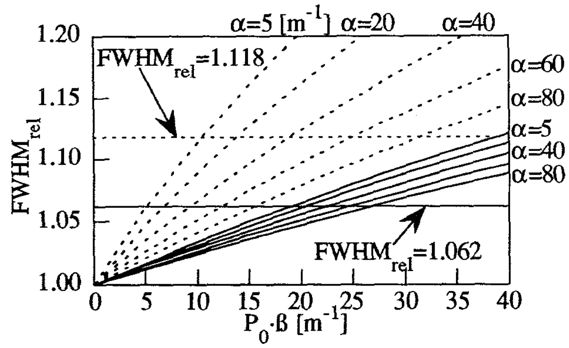

figure 3 The relation between the pulse width change and $P_0 \cdot \beta$ for two different lengths of the non-linear interaction region. The horizontal lines correspond to the measurements.

$\cdots\cdots$: L_{pol} = 4 cm, —— : L_{pol} = 1 cm.

With the aid of equations 1, 2 and 3 the TPA of DANS can be calculated from the experimental data. The final conclusions to be drawn are:

- $\alpha_{DANS} = 60 \pm 20$ [m^{-1}] (2.5 ± 1 [dB/cm])
- $\alpha_{SiON} = 25 \pm 15$ [m^{-1}] (1 ± 0.5 [dB/cm])
- $\beta_{m,DANS} = 4 \pm 2$ [pm/W]

Conclusions

A simple method for determining the TPA is described. The value of the two photon absorption as given by Stegeman[4] is 10pm/W and is in reasonable agreement with our results.

References

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